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# Optimal Selection and Allocation of Sectionalizers in Distribution Systems Using Fuzzy Dynamic Programming

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## Abstract

This paper describes a calculation strategy that allows determining the optimal number and placement of sectionalizing switches in MV radial distribution networks, in correspondence to technical, regulatory and economical aspects. A formulation that takes into account the investment, maintenance and power interruption costs has been developed, seeking for a reduction in total costs while taking care of the regulatory and technical aspects. A multicriteria optimization procedure allows incorporating in the calculating process various quality indicators which can be either global or individual indexes. This way of formulation makes the proposal flexible as well as applicable to allow including aspects that were not considered in previous papers. The solution methodology is mainly based on dynamic programming, fuzzy logic, heuristics and economic analysis techniques. Given its flexibility, the proposed tool is easily adapted to real distribution systems, by considering the individual requirements of each network. The solutions obtained in simulations are oriented to help decision-making for the operator.

**Keywords:** Distribution Systems, Protection, Fuzzy Logic, Reliability

## 1. Introduction

One of the critical requirements of any distribution system is that related to the service-quality and reliability requirements demanded by their users. For that, the distribution utilities must make significant investments to meet these service-quality and reliability standards. Therefore, network design engineers and system planners focus their effort on the network design, the type of electric protection to choose from, and the placement of sectionalizing switches.

The selection of a number of sectionalizing switches and their correct placement in the MV distribution network is a planning task that has not been solved entirely. Most distribution utilities, however, resort to their own practical experience, using the information from their operators and clients and adopting solution methods that are hardly optimal.

The purpose of the present work is to develop a calculus strategy that allows determining the placement and optimal number of sectionalizing switches in an MV radial distribution network, by linking the technical, regulatory and economic aspects.

## 2. State-of-the-Art

First, Many research papers have dealt with the problem of optimal distribution protection design [1,2].

The problem of optimal placement of sectionalizing devices in radial networks considering a balancing approach between investments and costs of Non-Supplied Energy (NSE) has an exact solution developed by V. Miranda [3] using dynamic programming. This approach has been upgraded through the years, with the inclusion of fuzzy values in the referential data, as shown in [4-6].

There are other solving techniques proposed. The application of a general procedure of combinatory optimization known as “simulated annealing” is proposed en [7], whereas [8] proposes using binary programming. Likewise in [3], work [9] indicates applying a combination of dynamic programming with techniques to reduce the data search-space.

References [7,10-12] resort to heuristic approaches. Though these do not guarantee the precision of the obtained results; besides, they demand long computing times, which, in all, render them inadequate for real MV networks.

 

After having reviewed the bibliography, we may conclude that there is no work that allows solving in an integral way the problem of sectionalizing switches allocation in the network. Not one considers the influence of all variables involved, the uncertainty in the information, while contemplating all technical constraints existing in a distribution system.

## 3. General Formulation

The problems in which reliability is included as an optimization criteria should be solved through a flexible methodology. That must allow including in the formulations the necessary reliability indexes according to the specific requirements of the system, and those of the customers as well. The problem thus stated will entail complex mathematical formulations, with many objectives to optimize (e.g., Total Costs, Frequency of Momentary Interruptions and NSE to the system, or to a particular load, etc.). Besides, considering that these indicators are not comparable one another and, therefore, cannot be integrated into a single objective function, the problem thus becomes one of multicriteria.

A possibility is to formulate the problem by considering the objective function "Total Costs", and including the other criteria as restrictions. Therefore, an example of a mathematical model for the problem of sectionalizing equipment allocation can be expressed as follows:

Objective Function:

$$Min\sum C_I + \sum C_A + \sum C_{O\&M} \quad (1)$$

Subject to:

MAIFI < MAXIM

MIFINi < MAXIMi

NSEi < MAXNSEi

NIFIi < MAXFIi

where:

CI = Annual Interruptions Costs [$]

CA = Annualized Investment Costs on Sectionalizing devices and Installations [$]

COyM = Annual Operative and Maintenance Costs of the Sectionalizing devices [$]

MAIFI = Mean Momentary Interruption Frequency of the Feeder.

MAXIM = Maximum number of momentary interruptions of the system.

MIFINi = Momentary Interruption Frequency Index at node i.

MAXIMi = Maximum number of momentary interruptions at node i.

NSEi = Non-Supplied Energy at node i [kWh-year]

MAXNSEi = Maximum ENS for a node i [kWh-year]

NIFIi = Node Interruption Frequency Index at node i.

MAXFIi = Maximum number of interruptions at node i.

Considering all the above analyzed aspects, and the fact that the arising problems differ in nature, it is not convenient to use a rigid methodology of solution. Rather, the approach must be flexible to allow choosing "optimization criteria" according to the regulations and client requirements.

As mentioned in 2 proposed solutions do not permit to consider the problem before formulated, in an integral way. Additionally, excessive calculation times make them unsuitable for its application to real-size MV systems.

The methodology for the current proposal uses an optimization technique that works with fuzzy dynamic programming which allows linking the regulatory and client requirements to the technical and economical aspects of the system operation.

## 4. The Proposed Algorithm

### 4.1. Fuzzy Decision and the Sectionalizing Device Allocation

The precursors of Fuzzy Logic, Bellman and Zadeh [13], defined three Basic concepts: fuzzy objective, fuzzy constraints and fuzzy decision. They analyzed the application of these concepts to the problems of decision-making under uncertainty.

If X is a set of possible alternatives to solve a decision-making problem, where the objective function G is a fuzzy set in X characterized by its membership function $\mu_G(x)$, and restriction R is also a fuzzy set in X with a membership function $\mu_R(x)$, then it is necessary that the objective and the restriction be satisfied simultaneously. Bellman and Zadeh defined a decision-making fuzzy set D as a result from the intersection of set G with set R.

$$D = G \cap R \quad (2)$$

Then, the membership function that characterizes the decision-making set D can be defined as:

$$\mu_D(x) = \min\left[\mu_G(x), \mu_R(x)\right] \text{ to all } x \in X \quad (3)$$

The membership function $\mu_D(x)$ denotes the membership degree of a decision $x \in X$ into the decision set D. Then, $\mu_D(x)$ can be used as a criterion to choose the optimal decision from the decision set D.

The optimal decision (x*) is such that it has the highest membership degree into the decision set D. This is equivalent to maximizing the membership value of function $\mu_D(x)$. Then, the decision maximization is defined by:

$$\mu_D(x^*) = \max_{x\in X} \mu_D(x) = \max_{x\in X}\left[\min\left\{\mu_G(x), \mu_R(x)\right\}\right] \quad (4)$$

In a general way, the fuzzy decision D resulting from k objective functions $G_1, G_2, \ldots, G_k$ and m restrictions $R_1.R_2, \ldots, R_m$ is therefore defined by:

$$D = G_1 \cap G_2 \cap \ldots \cap G_k \cap R_1 \cap R_2 \cap \ldots \cap R_m \quad (5)$$

And the corresponding maximization decision is:

$$\mu_D(x^*) = \max_{x\in X} \mu_D(x) = \\ = \max_{x\in X}\left[\min\left\{\mu_{G_1}(x), ..\mu_{G_k}(x), \mu_{R_1}(x), .., \mu_{R_m}(x)\right\}\right] \quad (6)$$

This means that, in the fuzzy decision defined by Bellman and Zadeh, the fuzzy objectives and restrictions take part like in the expression for the membership function of D. However, depending on the case at hand, and when the fuzzy objectives and constraints are not equally important, it would be possible to employ weighing coefficients to incorporate the relative importance between them.

The solving procedure in choosing the optimal alternative to locate the sectionalizing device can be stated as an optimization problem. It considers modeling the objective function (which could be, for example, the total costs) and the constraints (such as the indexes for permanent and momentary interruptions; the index of interruption duration, etc.) by means of the fuzzy sets theory. The solving procedure in the decision-making set results from the intersection of the fuzzy sets involved, such as:

$$D = C_T \cap SAIFI \cap SAIDI \cap \mathrm{MAI}FI \cap NSE_i \quad (7)$$

where:

D: Fuzzy set of Decisions

CT: Fuzzy Set of Total Costs

SAIFI: Fuzzy Set of Interruption Frequency of the System

SAIDI: Fuzzy Set of Interruption Durations of the System

The maximization decision will be:

Then, the problem thus stated can be interpreted as one of decision making that involves choosing an alternative among the set of feasible ones that satisfies the objectives and the constraint set simultaneously.

When applying the fuzzy set theory to the decision making formulation, it can be noted that both, the objectives and the constraints, are mapped into the same fussy space [0,1], as opposed to a traditional optimization problem, where the objective function values are used straightforwardly.

Stated this way, the solution method will find an alternative for locating the sectionalizing device based on a set of criteria, in which the regulatory aspects can also be modelled. Besides, the other alternatives can also be made available ordered according to the fuzzy decision membership value.

To some constraints (SAIDI, SAIFI, etc.), the current quality regulations state a limit value from which the utilities start being penalized. The above suggests that they can be treated properly from the modelling of the membership function.

There are a number of alternatives to define the membership functions that are valid to define fuzzy sets as well. They should be selected carefully, though, regarding the characteristics to be represented and the problem to be solved, as well as its logical structure in order to define its associated linguistic value.

Finally, the objectives and constraints may show different importance degrees. The planner or decision-maker shall ponder this importance among objectives and constraints, according to his preference or judgment criterion. Some pondering methods used are detailed in references [13,14,15]. This paper uses the method proposed by T.L. Saaty [14].

Exponential pondering will be used in evaluating the fuzzy sets involved in the decision-making process. Then, the decision making fuzzy set will be:

$$D = C_T^{p_{CT}} \cap SAIFI^{p_{SAIFI}} \cap SAIDI^{p_{SAIDI}} \\ \cap MAIFI^{p_{MAIFI}} \cap NSEi^{p_{NSEi}} \quad (9)$$

This model is adequate to transform an idiomatic quantifier into quantifying measurements. In general, values of $p > 1$ decrease the membership degree, and values of $0 < p < 1$ increase the membership degree of each element into the set.

## 4.2. Fuzzy Dynamic Programming (FDP)

The FDP method requires a set of discrete-variables whose values, represented by their respective membership functions, are mapped onto the decision making fuzzy set, which incorporates both the objectives and the constraints. The result involves evolving along an optimal trajectory formed by following the criteria that every optimal state stems from the variant that is linked to the maximum membership value of the decision fuzzy set.

The following terms will be used to define the FDP model proposed by Bellman and Zadeh applied to the problem of the sectionalizing device allocation.

$$\mu_D(x^*) = \max_{x\in X} \mu_D(x) == \max_{x\in X}\left[\min\left\{\mu_{CT}(x), \mu_{SAIFI}(x), \mu_{SAIDI}(x), .., \mu_{MAIFI}(x), \mu_{NSE_i}(x)\right\}\right] \quad (8)$$

$s_i$: State Variables (rigid), i = 1, 2, ... M, where $S = \{\tau_1,...,\tau_M\}$ is the set of values allowed by the state variables (dominion).

$x_i$: Decision variables (rigid), i = 1, 2, ... M, where $X = \{\alpha_1,...,\alpha_M\}$ is the set of possible decisions.

N : Number of stages

M : Number of possible states

For each stage k, k = 1,,..., N, the following is defined:

A fuzzy constraint $C_k$, that bounds the decision-making space. It is featured by its membership function $\mu_{C_k}(d_k)$.

A fuzzy objective G characterized by its membership function $\mu_G$

The problem to be solved is that of finding a maximization decision:

$$D^* = \{d_i^*\} \quad i = 0,...,M \quad \text{for a given state "s"} \quad (10)$$

The model for establishing the decision set will be that of the "intersection" between the restrictions and the objective functions. That is:

$$D = \bigcap_{t=1}^{R} C_t \cap G \quad (11)$$

with R = number of restrictions

Once the membership functions of the objective function and the constraint are defined, the value of the membership decision function can be determined, for each one of the possible links proposed by the FDP search process Thus, using the operator min (intersection)[1] to aggregate the fuzzy restriction and objective function, the membership function of the decision fuzzy set is:

$$\begin{aligned}&\mu_D(k,s_j,x_i)\\&= \mathrm{M}in\{\mu_{C1},..,\mu_{C_R},..,\mu_G(k,s_j,x_i,\mu_D^*(k-1,s_i))\}\end{aligned} \quad (12)$$

Where (k-1, $s_i$) denotes the optimal decision for state $s_i$ in stage k-1.

The optimal decision in FDP is that one presenting the highest membership value to the decision set. The membership function of the maximized function for stage si of stage k is:

$$\mu_D^*(k,s_j) = \max_{i=1,..M}\left[\min\{\mu_{C1},..,\mu_{C_R},..,\mu_G(k,s_j,x_i,\mu_D^*(k-1,s_i))\}\right] \quad (13)$$

The membership function of the maximized decision for stage k is:

$$\mu_D^*(\mathrm{k}) = \max_{j=1,..M}\max_{i=1,..M}\left[\min\{\mu_{C1},..,\mu_{C_R},..,\mu_G(\mathrm{k},\mathrm{s_j},\mathrm{x_i},\mu_D^*(\mathrm{k}-1,\mathrm{s_i}))\}\right] \quad (14)$$

where $\mu^*_D$(k) denotes the optimal decision for stage k. The complete solution will be determined recursively. The "backward" technique of dynamic programming is used.

It should also be considered into the formulation the possibility of installing equipment with reclosing capabilities. This means that, at each stage, there will be two alternatives, namely: locate equipments capable of reclosing and locate equipment without capability of reclosing. Therefore, in the optimal decision, this aspect shall be incorporated. The modified expression to define the optimal decision for stage k, $\mu^*_D$(k), with this variant, is shown below:

$$\mu_D^*(\mathrm{k}) = \max_{j=1,..M}\max_{\substack{i=1,..M\\e_{i(j)}=0,1}}\left[\min\{\mu_{C1},..,\mu_{C_R},..,\mu_G(\mathrm{k},\mathrm{s_j},\mathrm{x_i},\mathrm{e_j},\mu_D^*(\mathrm{k}-1,\mathrm{s_i},\mathrm{e_i}))\}\right] \quad (15)$$

where $e_{i(j)}$ will be 1 if the equipment has reclosing capability; and 0 when lacking it.

Finally, expression (15) will allow including as many optimization criteria (objectives and constraints) as necessary, without modifying the general structure of the algorithm. This brings enough flexibility to solve the various problems arising from regulations and client demands. It should be kept in mind that every criterion shall have a different weight as regards its relative importance. The algorithm calculus sequence along with its main features is presented in **Figure 1**.

The calculation procedure is as follows:

1) The procedure starts (k = 0) by considering that there is not any sectionalizing device in the feeder, excepting the feeder circuit breaker.

2) The value of the total costs and the reliability indexes (SAIFI, MAIFI, SAIDI, etc.) are computed, altogether with their respective membership values. The membership value of the decision $\mu_D(0)$ is found by using the operator *min* (intersection).

3) The stage value is increased ($k$ = 1). All reliability indexes are computed, with their respective membership values associated to each state *j*. That is, the location of sectionalizing switches is simulated, one at a time. Then, applying the operator *min*, the membership value of the decision $\mu_D(j,1)$[2] is found for each possible state.

4) According to the maximum value of the $\mu_D(j,1)$, the

[1]In the theory of fuzzy sets, the operation "intersection" between two fuzzy sets *A* and *B*, with their respective membership functions $\mu_A$ and $\mu_B$, is defined as: $C = A \cap B$; and its membership function is: $\mu_C = min(\mu_A, \mu_B)$. That is, the membership value of the resulting fussy set *C* is the minimum value of the membership functions of fuzzy sets *A* and *B*.

[2]$\mu_D(j,k)$ represents the membership function of the decision for state *j* and stage *k*.

 

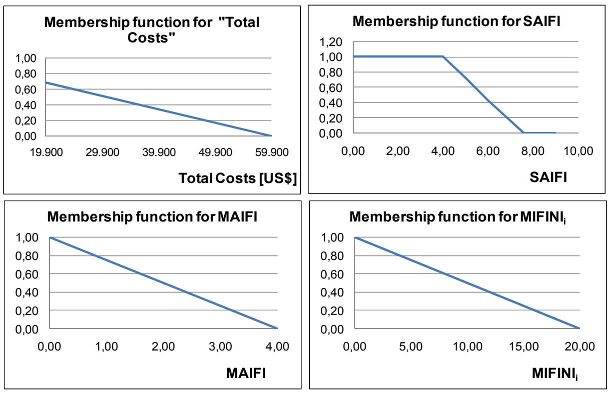


**Figure 1. Membership functions used in FDP for the real system.**

$\mu_D^*(1)$ are determined as the best alternative for stage 1.

5) Stage (k = k + 1) is increased.

6) At each state j, and for all possible links with stage k-1, the reliability indexes are computed together with their respective decision membership values for each possible link by applying the operator min. That is, the location of the k-th sectionalizing equipment is simulated, considering all the links with the previous stage.

7) For each state j, considering the maximum value of the membership functions resulting from each link with stage *k*-1, the value $\mu_D(j, k)$ is established.

8) According to the maximum value of the $\mu_D(j, k)$, the $\mu_D^*(k)$ is found as the best alternative for stage *k;* besides, the link with the associated stage *k-1* is determined as well.

9) Steps 5, 6, 7 and 8 are then repeated until the benefits resulting from the best alternative of stage $k + 1$ become lower than those reached by the best alternative of stage *k*.

10) It is made $N = k$ , and *N* is defined as the stage of optimal benefit.

11) According to the values of $\mu(j,N)$ (fuzzy decision for state *j* of stage *N*), the optimal solution is found. From it, and following the backward technique and according to the optimal decisions, the optimal trajectory is rebuilt to determine in which branch the sectionalizing switch will be installed. Besides, it is possible to re-construct all the paths for each state *j* of stage *N*.

## 5. Application

In order to show the practical application of the proposed methodology, a number of simulations were performed using a real MV feeder that supplies energy to a region of the Province of Azuay, south of the Republic of Ecuador. In the first part of its layout, it supplies a typically urban sector; then, it supplies power to several rural areas. In addition, the line serves several industrial customers.

**Table 1** shows the feeder most important characteristics and parameters (according to information obtained in 2002).

The historical data recorded by the distribution utility allow establishing the interruption times and failure rates presented in **Table 2**.

Some considerations were made for the simulations. First, at the feeder head there is a circuit breaker with protective relays and automatic reclosing relay.

Second, it is assumed that all sectionalizing and protection equipments are 100% reliable, and that the supply alternatives are always available. Third, capacity constraints will be considered for transformers and line for the cases of load transference. Finally, to compute the NSE, the average demand value of the feeder loads will be used.

**Table 1. Feeder characteristics.**

| Type | (Urban-Rural) |
|---|---|
| Installed load [kVA] | 9,560 |
| Number of MV/LV transformers | 240 |
| Total circuit length [km] | 48.7 |
| Number of branches | 358 |
| Voltage level [kV] | 22.0 |
| Peak load [kW] | 3,106 |
| Energy [kWh-year] | 14,992,638 |
| Load factor | 0.551 |
| Average load [kW] | 1,711 |
| Number of customers | 4,553 |
| NSE [kWh-year] | 29,908 |
| SAIFI [Interruptions/Customer-year] | 7.54 |
| SAIDI [Hours/Customer-year] | 15.24 |
| MAIFI [Hours/Customer-year] | 0.00 |

**Table 2. Time and failure rates for the feeder.**

| | |
|---|---|
| Isolation Time (ts) | 1 hour |
| Transference time ( tt ) | 1 hour |
| Time for failure fixing ( tr ) | 5 hour |
| Urban permanent-failure rate ( $\lambda$pu) | 0.181 failure/year·km |
| Rural permanent-failure rate ( $\lambda$pr) | 0.198 failure/year·km |
| Urban momentary-failure rate ( $\lambda$tu) | 0.289 failure/year·km |
| Rural momentary-failure rate ( $\lambda$tr) | 0.317 failure/year·km |

 

The protection device cost, its useful life, the discount rate, the unitary cost of NSE and the operation and maintenance costs are all detailed in **Table 3**.

### 5.1. Case 1: Using Conventional Dynamic Programming

With the above data and considerations, the optimal location of the feeder's reclosing devices will be determined using Conventional Dynamic Programming (DP) with the minimization objective function: "Total Costs". **Table 4** shows the detailed results of the best two possible alternatives.

Alternative 1 (3 reclosing and 1 interconnection device) is the best solution, with an annual total benefit of US$ 13,730. Alternative 2, with two interconnection and 3 reclosing devices is also a good solution. The SAIFI, SAIDI and MAIFI values are practically the same for each alternative, and the NSE is slightly lower for the second one. But, because this alternative has one additional interconnection device, the benefit results about 12% smaller than with Alternative 1. This means that, for this feeder, to count with more than one tie point does not bring along a greater benefit; even though it does improve the quality indexes, this improvement is minimal.

### 5.2. Case 2: Using Fuzzy Dynamic Programming

In order to illustrate the advantage of applying FDP to the previous network, in addition to looking for minimizing the total costs, it will be sought to minimize the momentary interruptions to an industrial customer whose load is significantly sensible to such interruptions. Besides, and as a third criterion, the feeder's interruption frequency will be minimized. The membership functions of the various adopted criteria are shown in **Figure 1**.

The values for the criteria weights employed in this case were computed according to what is stated in 4.1.

Then, the decision making problem, considering the weights value, results as follows:

$$D = C_T^{2.238} \cap SAIFI^{0.6824} \cap MIFINI_i^{0.998} \qquad (16)$$

The results are presented in **Table 5**, which shows the total costs for the best solution alternatives, and the values for the feeder indexes NSE, SAIFI, SAIDI and MAIFI, and the momentary interruption index (MIFINi) at the node that supplies power to the industrial customer.

Moreover, **Table 5** specifies, for both alternatives, the number of equipments to be installed, making a difference between equipments that must (or not) have reclosing capacity.

Alternative 1 with 3 protection devices (2 with reclosing capabilities and 1 without them) and 1 interconnection device, is the best solution.

By comparing these figures with the results obtained with DP in **Table 4**, it can be seen that, even though the values for NSE, SAIDI, SAIFI are slightly greater, the MAIFI value is smaller and, above all, the MIFINi index at the client's node is substantially lower: 2.23. Compared with the best alternative using DP, i.e. 6.23, the FDP solution is 64.2% lower.

On the other hand, the NSE value has increased scarcely in 0.44%, and the benefits have decreased about US$ 639 a year –a negligible value when contrasted with

**Table 3. Annual costs and financial costs.**

| | |
|---|---|
| Useful life of equipment and installations | 15 years |
| Annual discount rate | 12% |
| Cost of sectionalizing equipment | US$ 10.000 |
| Cost of NSE kWh<br>Residential Customers<br>Commercial Customers<br>Industrial Customers | <br>US$ 1.0 kWh<br>US$ 1.0 kWh<br>US$ 2.0 kWh |
| O&M Costs | 2% of investment costs |

**Table 4. Results using DP.**

| | Alt. 1 | Alt. 2 |
|---|---|---|
| # of interconnection devices | 1 | 2 |
| # of sectionalizing devices | 3 | 3 |
| NSE | 9,505 | 9,485 |
| Benefits [US$] | 13,730 | 12,082 |
| SAIFI | 1.57 | 1.57 |
| SAIDI | 5.79 | 5.78 |
| MAIFI | 5.07 | 5.07 |

**Table 5. Results using fuzzy dynamic programming.**

| | Alt. 1 | Alt. 2 |
|---|---|---|
| Interconnection Equipment | 1 | 2 |
| Sectionalizing Equipment with reclosing capabilities | 2 | 2 |
| Sectionalizing equipment without reclosing capabilities | 1 | 1 |
| NSE [kWh] | 9,547 | 9,485 |
| Benefits [US$] | 13,091 | 12,082 |
| SAIFI | 1.57 | 1.57 |
| SAIDI | 5.81 | 5.78 |
| MAIFI | 4.07 | 4.07 |
| MIFINi | 2.23 | 2.28 |

the upgraded quality service rendered to the customers and, specifically, to the industrial one.

From the above analysis, it can be concluded that the solution alternatives with similar costs present as well very differing MAIFI and MIFINi values. The methodology with FDP allows identifying solutions that have very convenient characteristics for certain reliability indicators, without having to jeopardize the economical aspects. It is here where the proposal of the work marks its advantage over other approaches.

It is thus shown that the method of FDP has an additional advantage over the conventional approach because it allows considering in the optimization process various decision-making criteria. In this case, considering the hypotheses of the example, three fundamental criteria were employed: Total Costs, MAIFI and MIFINi.

Finally, because this is a combinatory-type problem, the computer times are significant and depend, mostly, on the network size under study, and the computing equipment available, *i.e.*, processing capacity and speed. When making computations on a 128 Mb RAM, 2GHz Pentium IV, the processing takes little less than 4 minutes. An important part of this time is used in computing the power flow needed to verify the technical constrains (voltage drop and loadbility of the elements)

On the grounds that the proposed methodology is meant to be applied in the planning processes, the computer times are adequate enough for this kind of studies.

## 6. Conclusions

- The problem of locating the sectionalizing equipment in MV distribution networks have certain properties that allow using FDP to find its solution, without having to make an exhaustive search. Indeed, the approach of analyzing all possible alternatives in real distribution networks is practically impossible to do, because it is a combinational-type problem.
- Considering that the problems always differ in some point, because the feeders present different characteristics, the rigid-solution methodologies turn to be impractical. Instead, the proposed solving approach allows choosing “optimization criteria” according to the network type, client requirements and service regulations, which renders it in a very flexible algorithm.
- The chance of stating the problem of sectionalizing equipment placement based on a set of criteria, with which the regulatory aspects can be modeled, besides incorporating specific conditions with the help of tools and concepts of fuzzy programming, allows considering, into a single framework, various hypotheses and specific requirements for optimization.
- The proposed methodology regards a static network; that is, it does not implicitly consider variations in the input data. But this fact does not prevent from including or interacting with long-term studies, where demand-growth, cost variations and regulatory changes have to be considered, because the proposed approach can be used with every variant in each year, within the long-term planning framework.
- The work has shown the effectiveness of the proposal to find the number and location of sectionalizing and protection devices for MV networks, regarding all specific conditions and constraints.
- From the comparative analysis made for two different scenarios –the first one considering only the total costs, and the second regarding additional optimization criteria through FDP- it was shown that using the algorithm adequately , very similar solutions are found, with comparable costs, though there are advantages with the latter solution because it allows considering other aspects. This is particularly useful for feeders presenting heterogeneous, sensible and/or sizable loads.
- Because the proposed methodology is meant to be applied in the planning processes, the computer times are adequate enough for this kind of studies.

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